The ellipticities of Galactic and LMC globular clusters

Simon P. Goodwin

Astronomy Centre, University of Sussex, Falmer, Brighton BN1 9QH, UK.

ABSTRACT

The correlations between the ellipticity and the age and mass of LMC globular clusters are examined and both are found to be weak. It is concluded that neither of these properties are mainly responsible for the observed differences in the LMC and Galactic globular cluster ellipticity distributions. Most importantly, age cannot be the primary factor in the LMC-Galaxy ellipticity differences, even is there is a relationship, as even the oldest LMC clusters are more elliptical than their Galactic counter-parts.

The strength of the tidal field of the parent galaxy is proposed as the dominant factor in determining the ellipticities of that galaxy's globular clusters. A strong tidal field rapidly destroys velocity anisotropies in initially triaxial, rapidly rotating elliptical globular clusters. A weak tidal field, however, is unable to remove these anisotropies and the clusters remain close to their initial shapes.

Key words:
globular clusters: general

1 INTRODUCTION

It has been observed that the globular clusters of the LMC (Large Magellanic Cloud) are significantly more elliptical than their Galactic counter-parts (Geisler & Hodge 1980; Frenk & Fall 1982; van den Bergh 1983; van den Bergh & Morbey 1984; Kontizas *et al.* 1989; Han & Ryden 1994). Indeed, there does appear to be a general and significant difference between globular cluster ellipticities according to the morphology of the parent galaxy (Han & Ryden 1994).

Kolmogorov-Smirnov tests of the ellipticity differences of the Galactic and LMC populations show that, at the 99.2% confidence level, the globular clusters have been drawn from different parent populations (the two distributions are illustrated in Fig. 1). In addition, there appears to be strong evidence that the Galactic globular clusters are oblate spheroids compared to an apparently triaxial LMC population (Han & Ryden 1994).

Studies of the ellipticities of the LMC globular clusters indicate that they correlate with luminosity/mass (van den Bergh 1983; van den Bergh & Morbey 1984; Kontizas *et al.* 1989). There is some debate in the literature upon the existence of a correlation of ellipticity with age within the LMC. Frenk & Fall (1982) discovered an apparent correlation, however van den Bergh & Morbey (1984) argued that this relationship would be effected by foreground absorption and no significant relationship exists. Kontizas *et al.* (1989) also found only a weak correlation with age.

This paper examines the correlations present in the LMC globular cluster system. The main question that is addressed is the origin of the differences between the LMC

and Galactic populations: are these differences in ellipticity due to dynamical evolution and of what sort?

2 ANALYSIS

A sample of globular clusters is analysed in an attempt to investigate the differences between LMC and Galactic populations. A sample of 25 LMC globular clusters has been collected from the literature, this is a smaller sample than used in a number of other studies due to the lack of clusters for which a number of different parameters have been well determined.

Table 1 summarises the attributes of the clusters: e_h is the ellipticity measured at the half-mass radius, M the mass, and S the age parameter defined by Elson & Fall (1985). It should be noted that the S parameter has a one-to-one relationship with the age type determinator used by Frenk & Fall (1982) and van den Bergh & Morbey (1984).

Figure 2 shows the age (S parameter) against ellipticity for 23 of the globular clusters in the sample. The lack of significant correlation is obvious even by eye. The lines on fig. 2 show the mean ellipticities when the data is placed in 4 bins by age (dotted line) or by number of clusters (dash-dot line). A statistical test using the sample correlation coefficient shows only a very weak correlation.

The strong correlation found by Frenk & Fall (1982) is highly dependent upon foreground absorption increasing the ellipticities of a number of their younger clusters. Once this effect has been removed the correlation disappears (van den
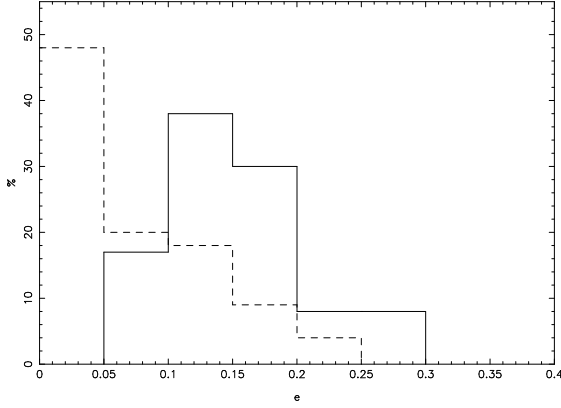
Figure 1. The ellipticity distributions of globular clusters in the LMC (full line) and Galactic (dashed line) from data in White & Shawl (1987) and Kontizas *et al.* (1989).

NGC	e_h [a]	$M/10^5 M_\odot$	S [a]
1711	0.22	2.2 [e]	20
1751	0.15	0.9 [e]	42
1755	0.13	1.2 [b]	24
1786	0.12	1.6 [e]	48
1806	0.12	0.9 [e]	40
1835	0.17	1.5 [e]	47
1846	0.23	1.3 [b]	40
1847	0.20	1.5 [e]	21
1850	0.09	3.4 [e]	21
1852	0.09		45
1854	0.12	1.8 [e]	25
1856	0.16	2.0 [e]	30
1861	0.14	1.9 [e]	
1885	0.13	0.6 [b]	28
1898	0.10	0.6 [b]	50
1903	0.10	1.0 [b]	23
1917	0.10	1.2 [b]	39
1953	0.16	1.5 [e]	29
1987	0.16		35
2004	0.20	0.4 [b]	15
2019	0.20	1.6 [e]	46
2031	0.21	0.3 [b]	27
2038	0.16	1.3 [e]	
2056	0.13	1.5 [e]	31
2107	0.12	0.9 [b]	32

Table 1. Comprehensive data for 25 LMC globular clusters available in the literature. [a] from Kontizas *et al.* (1989), [b] from Chrysovergis, Kontizas & Kontizas (1989), [c] from Elson (1992), [d] from Mateo (1987) and [e] from Kontizas, Chrysovergis & Kontizas (1987).

Bergh & Morbey 1984). Such a correlation is also absent in the more uniform sample of Kontizas *et al.* (1989).

It should be noted that ellipticity is not a simple quantity. Ellipticity varies with radius (Kontizas *et al.* 1989; Kontizas *et al.* 1990) and so is difficult to define. The half-mass radius ellipticities of Kontizas *et al.* (1989) have been used as they form a more consistent set. The use of ellipticities from Frenk & Fall (1982), however, would produce an ellipticity-age relationship (although van den Bergh & Morbey 1984
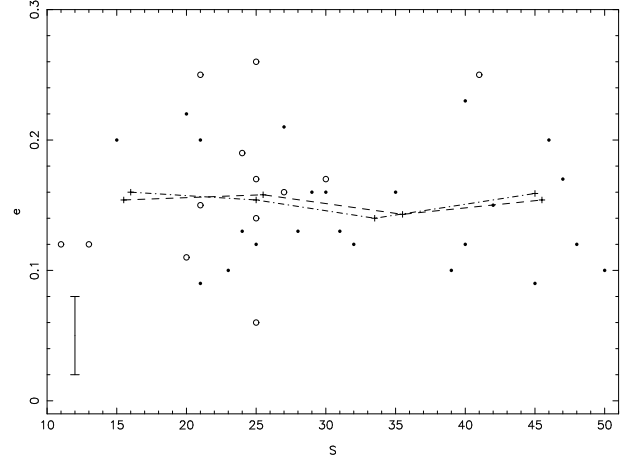

Figure 2. Ellipticity-age relationship for LMC globular clusters. Filled circles are data from table 2 while open circles are other clusters for which e_h and S are given in Kontizas *et al.* (1989). The estimated errors of ±0.03 are illustrated by the error bar in the lower left corner. The dotted line shows the mean ellipticities in 4 age bins, and the dash-dot line shows the mean ellipticities in 4 numerical bins.
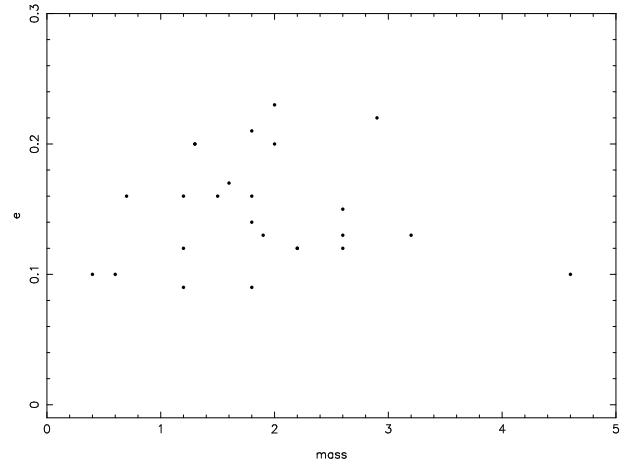

Figure 3. Ellipticity-mass relationship for LMC globular clusters.

argue that it is not significant). The existence of a stronger relationship should not be discounted entirely, although it would not appear to be the dominant relationship.

The ellipticity-mass relationship illustrated in fig. 3 also shows a surprising lack of correlation in contradiction to the results of van den Bergh & Morbey (1984) and Kontizas *et al.* (1989). This figure is similar to fig. 5 of Kontizas *et al.* (1989) but the inclusion of masses for NGCs 2004 and 2031 (from Chrysovergis *et al.* 1989) help remove a correlation. Again the sample correlation coefficient test upon the data shows only a weak correlation.

There also appears to be no significant correlation between the age and mass of LMC globular clusters. It would appear as if neither age nor mass are the dominant factors in the differences in ellipticities between the LMC and Galactic globular clusters.

3 DISCUSSION

The main differences between the LMC and Galactic globular clusters may be summarised briefly as:

(i) The LMC globular clusters *at all ages* are significantly more elliptical than the Galactic population.

(ii) The shapes of the LMC (and SMC) globular clusters are well-represented by triaxial spheroids while those of the Galaxy (and M31) are oblate spheroids (Han & Ryden 1994)

Han & Ryden (1994) attribute (ii) to age differences between the two populations, the older Galactic population being more relaxed and hence more spherical then the younger LMC population. However, this cannot be the entire picture as (i) indicates that even old LMC clusters are more elliptical and triaxial than coeval Galactic globular clusters.

In most other respects the Galactic and LMC globular cluster populations are very similar. The LMC globular clusters have masses in the range 10^4 to a few $\times 10^5 M_\odot$ (Elson, Fall & Freeman 1987; Chyrsovergis *et al.* 1989; Lupton *et al.* 1989) and core radii of $0.5 < r_c/\text{pc} < 6.8$ (Elson 1991). These values are very similar to those of the Galactic globular clusters $10^4 < M/M_\odot < 10^6$ (Mandushev, Staneva & Spansova 1991) and $0.1 < r_c/\text{pc} < 19$ (Djorgovski 1993).

Young globular clusters appear always to show high ellipticity. In addition to the LMC, recent HST observations of super star clusters (assumed analogous to young globular clusters) in NGC 1569 also appear to show high ellipticities (O'Connell, Gallagher & Hunter 1994). If high ellipticity, and presumably a triaxial shape, is a general property of a young globular cluster, a question must be raised as to why the old Galactic population have had their original structures modified while the old LMC population remain unchanged, especially as they appear so similar in most other respects.

This being the case some dynamical influence must be invoked to explain the differences in the populations, it is proposed that this factor is the strength of the tidal field of the parent galaxy. If globular clusters form as triaxial spheroids (with a suitably anisotropic velocity dispersion) then the action of a strong tidal field as they orbit about a galaxy will be to force the velocity dispersion to isotropy. In other words, the cluster will loose its initial triaxiality and become more spherical.

The simulations of Longaretti & Lagoute (1996a,b) of rotating globular clusters also show the effects of a strong tidal field in reducing the half-mass ellipticities of globular clusters, by removing angular momentum from the cluster. Globular clusters experiencing a higher tidal force (lower Galactocentric radius) become spherical more rapidly than other clusters (figs. 7e and 8e in Longaretti & Lagoute 1996a).

If the tidal field is dominant in reducing ellipticity then the observed dependence of ellipticity upon galaxy morphology (Han & Ryden 1994) would be expected. Further, the slightly higher ellipticities observed in the SMC than in even the LMC (Kontizas *et al.* 1990, Han & Ryden 1994) would also be expected due to the weaker tidal field of the SMC.

One might still expect an ellipticity-age relationship in this scenario (of the sort noted by Frenk & Fall 1982). The apparent absence of such a relationship is presumably due to the inability of the LMC tidal field to modify the shapes of its globular cluster population significantly. Galactic globular clusters are presumably all old enough to have had their initial triaxiality destroyed and their shapes are mainly due to rotation (White & Shawl 1987) and, possibly, shocking. The most elliptical Galactic globular clusters are found to have low Galactocentric radii and (for all but 2 clusters) low heights above the Galactic disc (using data from White & Shawl 1987 and Djorgovski 1993). This may be explained as the result of recent tidal shocking (disc or bulge) reintroducing an anisotropy into the velocity dispersion. This may account for the large spread of ellipticities at low Galactocentric radii ($0.00 < e < 0.27$ at $R_G < 6\text{kpc}$).

4 SUMMARY

The tidal field of the parent galaxy is proposed as the major factor determining the ellipticities of its globular cluster population. If the original shapes of all globular cluster populations are highly elliptical and triaxial then a strong tidal field will act to reduce that triaxiality and force the clusters to a more isotropic distribution and spherical shape. The effectiveness of this process is limited in weak tidal fields (such as those of the LMC and SMC) leading to the ellipticities of even the oldest globular clusters remaining at their high initial values.

5 AKNOWLEDGEMENTS

REFERENCES

Chrysovergis M., Kontizas M., Kontizas E. 1989, A&AS, 77, 357
Djorgovski S. 1993, in Structure and Dynamics of Globular
    Clusters, eds. Djorgovski S., Meylan G., ASP Conference
    Series vol. 50 (ASP:San Fransisco), p373
Elson R. A. W. 1991, ApJ Suppl., 76, 185
Elson R. A. W. 1992, MNRAS, 256, 515
Elson R. A. W., Fall S. M. 1985, ApJ, 299, 211
Elson R. A. W., Fall S. M., Freeman K. C. 1987, ApJ, 336, 734
Frenk C. S., Fall S. M. 1982, MNRAS, 199, 565
Geisler D., Hodge P. 1980, ApJ, 242, 66
Han C., Ryden B. S. 1994, ApJ, 433, 80
Kontizas E., Kontizas M., Sedmak G., Smareglia R. 1989, AJ, 98,
    590
Kontizas E., Kontizas M., Sedmak G., Smareglia R.,
    Dapergolas A. 1990, AJ, 100, 425
Kontizas M., Chrysovergis M., Kontizas E. 1987, A&AS, 68, 147
Longaretti P-Y., Lagoute C. 1996a, A&A, 308, 441
Longaretti P-Y., Lagoute C. 1996b, A&A, 308, 453
Lupton R. H., Fall S. M., Freeman K. C., Elson R. A. W. 1989,
    ApJ, 347, 201
Mandushev G. I., Staneva A., Spansova N. 1991, A&A, 252, 94
Mateo M. 1987, ApJ, 323, L41
O'Connell R. W., Gallagher J. S., Hunter D. A. 1994, ApJ, 433, 65
van den Bergh S. 1983, PASP, 95, 839
van den Bergh S., Morbey C. L. 1984, ApJ, 283, 598
White R. E., Shawl J. 1987, ApJ, 317, 246